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NATURAL ENEMIES
OF INVASIVE KNOTWEEDS IN THE PACIFIC NORTHWEST

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Cover photo Native adult chrysomelid beetles (*Galerucella nymphaeae)* and eggs on a giant knotweed leaf. Photo by Fritzi Grevstad

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Natural Enemies of Invasive Knotweeds in the Pacific Northwest

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Abstract

Invasive knotweeds include several species of shrub-like perennial herbs in the family Polygonaceae: Japanese knotweed (*Fallopia japonica*), giant knotweed (*Fallopia sachalinenis*), and Bohemian (or hybrid) knotweed (*Fallopia x bohemica*). Invertebrates associated with knotweed leaves, stems, and roots were sampled in Oregon, Washington State, and southeastern Alaska (2004, 2005) as potential biological control agents. In Oregon and Washington, a total of 765 herbivorous invertebrates, comprising 23 families and ten orders, were collected from 71 sites. In Alaska, 833 individuals representing 67 families in 14 orders (including herbivores and predators) were collected at five knotweed sites. We observed that a majority of foliar invertebrates were probably using the leaves as resting or hunting habitat. However, we identified 17 species of herbivorous species in Oregon and Washington and seven species in southeastern Alaska that appeared to be capable of using the plant for both feeding and development, although never at densities high enough to cause severe damage to the plant. In addition, although limited in extent, a wide variety of leaf damage was observed. In most cases the cause of damage could not be identified. Within stems and roots of knotweed, only 14 individual invertebrates were collected. Only about 2% (nine of 550 stems examined) of stems were clearly damaged in the interior, and contained frass and necrotic tissue suggestive of invertebrate feeding. Four percent (245 out of about 5950 examined) of examined root sections had some kind of interior damage. The few invertebrates we observed appeared to be using the interior as resting habitat, and were species not known to be interior stem or root feeders (e.g. snails, slugs, thrips, soldier beetles, ground beetles). We did not find any flower or seed feeders. Our results are consistent with other knotweed surveys conducted in the northeastern United States and in Europe, indicating low numbers of potential herbivores and low levels of feeding damage in invasive ranges.

Introduction

Invasive knotweeds are a complex of species of shrub-like perennials, family Polygonaceae, that were introduced intentionally into North America as ornamentals in the late 1800s. They include Japanese knotweed (*Fallopia japonica* (Houtt.) Dcne.), giant knotweed (*Fallopia sachalinensis* (F. Schmidt) R. Decr.), and a hybrid between these two, Bohemian knotweed (*Fallopia x bohemica* (Chrtek & Chrtková) J. P. Bailey). The various species are recorded from five Canadian provinces and 40 U.S. states (Shaw and Seiger 2002; Barney 2006). These plants crowd out native vegetation (Sukopp and Sukopp 1988), degrade critical fish and wildlife habitat (Seiger 1997), increase the potential for erosion (Child et al. 1992), and reduce recreational opportunities (Shaw and Seiger 2002). The plants are fast-spreading and difficult to control (Shaw and Seiger 2002).

The USDA Forest Service (FS) is developing a classical biological control (biocontrol) program, using natural enemies (agents) found in the native range of Asia, against the three varieties of knotweed. For several reasons, prior to introducing new natural enemies it is essential to document the existing community of natural enemies that use the target weeds as hosts. It is important to know whether any of the Asian biocontrol agents being considered already occur in the U.S. Documenting the existing herbivore community allows us to consider potential interactions between native and introduced natural enemies. For example, closely related species may compete with or share parasites or diseases. Finally, if existing natural enemies are found to be locally effective, there is the possibility for redistributing them as biocontrol agents in the U.S.

Prior to this study, little was known about the natural enemies of invasive knotweeds in western North America. As part of a larger nationwide effort, we undertook surveys of the natural enemies of knotweeds in the Pacific Northwest, including Alaska, Oregon and Washington State. The objectives of this study were to: 1) determine which species of invertebrates are currently using invasive knotweeds as hosts; 2) document levels of damage caused by the various herbivores/pathogens; 3) compare natural enemies found on knotweed species in the Pacific Northwest with those found in other regions of the U.S. and Europe, and to the pool of potential candidate species found in Asia; and 4) identify potential release sites for future biocontrol agents.

Knotweed Taxonomy and Nomenclature

The group of invasive plants commonly referred to as knotweeds includes three closely related and interbreeding species in the genus *Fallopia* and one species of *Persicaria*. All are in the tribe Polygoneae within the family Polygonaceae. Nomenclature in the Polygonaceae has been in flux, and so these species all have multiple scientific names in common use. The names we have elected to use are consistent with the *Flora of North America, Vol. 5* (Freeman et al. 2004) and reflect recent molecular relationships (Lamb, Frye and Kron 2003; Sanchez et al 2009). *Fallopia sachalinensis* (syn. *Polygonum sachalinense, Reynoutria sachalinensis*), or giant knotweed, is native to northern Japan and Sachalin Island. *Fallopia japonica* (syn. *Polygonum cuspidatum, Reynoutria japonica*), or Japanese knotweed, is native to southern Japan, Korea, and parts of China. Bohemian or hybrid knotweed, *Fallopia* x *bohemica* (syn. *Polygonum* x *bohemicum*), is a fertile hybrid that occurs from crosses between these two species (Hollingsworth and Bailey 2000).

The three *Fallopia* species are best distinguished by leaf size and shape as well as the presence or absence of leaf hairs (see Zika and Jacobsen 2003). *Fallopia sachalinensis* has very large heart-shaped leaves with fine hairs on the underside. *Fallopia japonica* has smaller leaves that are squared off at the base. *Fallopia x. bohemica* has leaves that are intermediate in these traits. Because of backcrossing and individual variation, it is not always easy to identify the species with certainty. While all three species are invasive and can be found throughout much of North America, *F. x. bohemica* appears to be most prevalent.

The fourth knotweed species that we surveyed was *Persicaria wallichii*, or Himalayan knotweed. This species is often referred to as *Polygonum polystachium*; however, the name "*Persicaria wallichii*" is preferable, because it more accurately reflects taxonomic relationships and is the name used in the *Flora of North America* (Freeman et al. 2004). Being in a different genus from the larger knotweeds, this species is not considered a target of biological control. However, *P. wallichii* is frequently grouped with the other knotweeds as a target of traditional weed-management programs.

Study Sites and Methods

Survey work was carried out by two independent teams, one team for southeastern Alaska, and one for Washington and Oregon). Study sites and methods differ slightly and are presented separately, below. A list of site locations, features, and knotweed species is provided in Appendix 1.

Oregon and Washington

Surveys for knotweed insects were carried out at a total of 71 sites in Washington and Oregon (Fig. 1), with an intent to include a variety of habitat types and all three knotweed species. The sites represented coastal regions (e.g. Big Creek, Oregon; Fig. 2, page 6), Willamette Valley and Puget Trough areas, Cascade foothills, and the Columbia Basin east of the Cascades. A majority of the sites (48) were either *F. japonica* or *F. x bohemica*, which are difficult to distinguish from each other, and which together are much more common than the other two species (Appendix 1). In our early surveys, we did not distinguish between *F. japonica* and *F. x bohemica* and so these cases are listed as *F. japonica/bohemica*. Ten sites surveyed were *F. sachalinensis* and ten were *P. wallichii*. The *Fallopia* species were found throughout the Pacific Northwest, while *P. wallichii* was found primarily in very close proximity to the coast. For each surveyed patch, we characterized the habitat as "upland," "streamside," or "upper stream bank," and the light level as shady, partial sun, or full sun. We also recorded the three or four dominant plant species in the surrounding plant community. Sites west of the Cascade Range were visited once in 2004, either during the period May 26–June 3, or June 21–July 2. The eastern Oregon and eastern Washington sites were visited August 17– 20, 2004. A subset of the sites in the vicinity of Astoria, Oregon, were surveyed a second time, September 7–10, 2004.

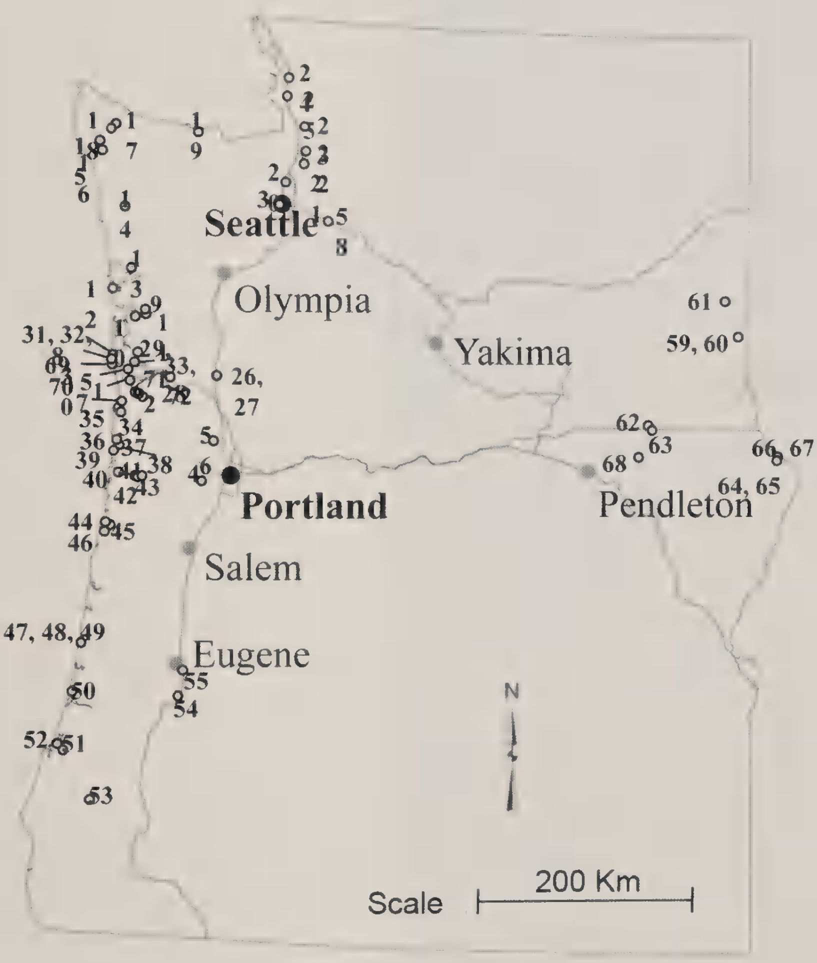

Figure 1 Map of knotweed sampling locations in Oregon and Washington, 2004 and 2005 (see Appendix 1).

Figure 2 Knotweed growing along Big Creek, OR, summer 2004. a) Patch. b) River bank. c) Second-growth forest. Photos by Fritzi Grevstad.

At each patch, ten stems were randomly selected from different sections of the knotweed patch. The leaves, exterior stems, and flowers (if present) were carefully searched for herbivorous invertebrates or diseases. Also, it was noted whether the herbivores were clearly feeding and/or reproducing on the plant vs. merely resting. The stems were then dissected to see if anything was feeding inside. Between five and ten root/rhizome sections were then dug and/or pulled up and dissected. After obtaining this quantitative data, the entire site was scanned for any additional herbivory or disease, which was noted separately from the quantitative data.

Alaska

Repeat surveys of invertebrates on knotweed were carried out at five sites in southeastern Alaska (Fig. 3). For each surveyed patch, we characterized the habitat as "upland," "streamside," or "upper stream bank," and the light level as "shady," "partial sun," or "full sun" (Appendix 1).

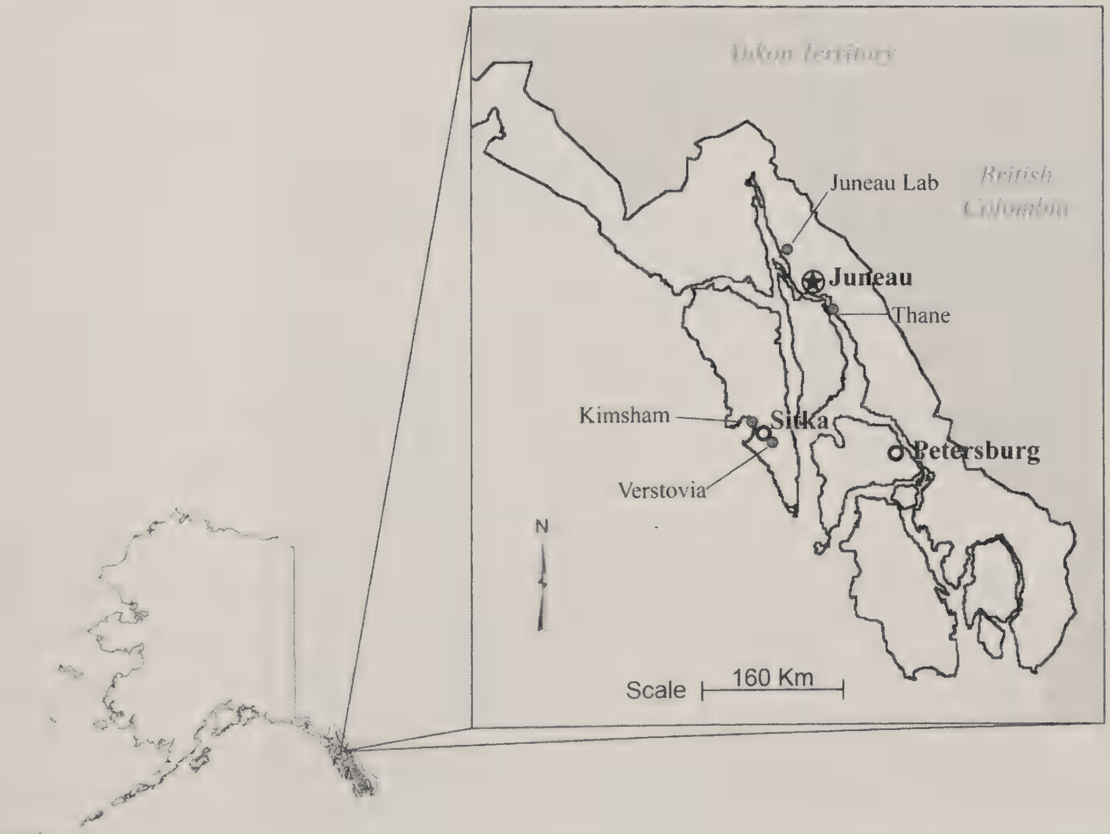

Figure 3 Map of knotweed sampling locations in southeatern Alaska, 2004 and 2005.

In Juneau, we sampled invertebrates at a site north of the city, adjacent to the Juneau Forest Service Lab (Fig. 4), and at a site along the beach south of the city (Thane Site). The Lab Site was a small patch of knotweed (<300 m^2) growing on one side of a natural slough. The Thane Site was a much larger patch of knotweed (~2000 m^2) growing in a thin band between a highway and the beach. Juneau sites were sampled on June 17 and September 20, 2004, and June 13–14 and September 11, 2005. The knotweed species was *F. japonica* at both Juneau sites.

Figure 4 Knotweed patches in Alaska. a) Near the Forest Service Laboratory in Juneau. b) City dump in Sitka, June 2004. Photos by Tom Huette.

In Sitka, we sampled at the city landfill, located on the northwest boundary of city's limits (Kimsham Site, Fig. 4, page 8), and along the main highway toward the eastern edge of the city (Verstovia Site). The Kimsham Site was a narrow band of knotweed (300 m^2) growing along the western edge of the landfill. The Verstovia Site was comprised of a few scattered patches of knotweed (total area ~250 m^2) growing along the edge of the highway. The Kimsham Site was sampled on June 18 and September 17, 2004, and on June 15 and September 13, 2005. The Verstovia Site was sampled on September 17, 2004, and on June 15 and September 13, 2005. The knotweed species was *F. x bohemica* at both Sitka sites.

In Ketchikan, we sampled only one site, the Ward Bay Site, on September 12, 2005. It is located approximately 10 km north of Ketchikan, on private property about 100 m inland from the bay. The knotweed species was *F. x bohemica.*

All five Alaska sites were characterized as having highly disturbed soils. In fact, observations by Mark Schultz and Tom Huette (USDA Forest Service) in southeastern Alaska indicate that knotweed currently infests only sites with disturbed soils. Unlike sites in the rest of the continental U.S., it appears knotweed has not invaded riparian areas in southeastern Alaska.

We sampled invertebrates in four distinct knotweed habitats: foliar, stem, root, and seed. We used the same standard protocol for each sample, following the methods developed by Blossey (2002). First, the foliage of about 30 complete stems was given a thorough, visual examination for invertebrates associated with the leaf surface. We also used a beating sheet to extract foliar arthropods. Second, each of the 30 stems was dissected along its entire length (tip to ground surface) to extract potential stem-boring invertebrates. Third, a pit, one meter square (1m^2), was excavated to examine all below-ground plant material for potential root-boring invertebrates. Roots were dissected by shaving half of the longitudinal sections with a whittling knife. Excavation ceased when few roots were encountered (usually a depth of about 0.8 meter). In addition to this standard protocol, about 300 seeds collected from Sitka in September 2004 were dissected for seed predators, and samples of roots from the Juneau sites were taken to Oregon in September for Berlese funnel extraction. Specimens collected from all four habitats were stored in alcohol, and labeled for future identification. Digital photos of potential leaf, stem, root, or seed-feeding damage were taken.

Weather for the three June, 2004, samples and the September, 2004, Sitka samples was ideal for invertebrate collection; the two September, 2004, Juneau samples were taken in a hard rain, and thus probably under-estimated foliar invertebrates. Weather in June and September, 2005, was generally favorable for collecting, with

occasional light rain interspersed with high clouds or sun. All specimens were identified to family level and reported as simple lists. Key herbivore species were sent to experts for genus- or species-level identification.

RESULTS

Oregon and Washington

Knotweed sites

Knotweed was found to be widely distributed throughout Oregon and Washington. While it was most prolific along the banks of rivers and streams of western Oregon and Washington, it was found in a surprising variety of habitats, including the edges of salt marshes, shaded floodplain forests, dry upland sites, roadsides, and waste areas.

Foliar herbivory and damage

At least 50 different species of herbivorous insects were found on knotweeds in Oregon and Washington. A majority of these were probably transient species not actually using the plant as a host; however, at least 17 species were clearly feeding on or using the plant as a host (Appendix 2a, b). All of these species were feeding on the leaves or outer stems of the plants. We found no stem borers or root feeders. The principle foliar-feeding herbivore species include spittle bugs, caterpillars of moths, aphids and other Homoptera, true bugs, beetles, and slugs. Each principle species found is described, below.

Within the Homoptera, the meadow spittlebug (*Philaenus spumarius* (Homoptera: Cercopidae)), was the most common and widespread species found feeding on knotweeds (c.f. Fig. 5a, page 13). It was sampled at a total of 27 sites, but present at even more. It was found in both nymph and adult stages on all three of the *Fallopia* species; Japanese knotweed (*Fallopia japonica*), giant knotweed (*Fallopia sachalinenis*), and Bohemian (or hybrid) knotweed (*Fallopia x bohemica*). It was found in coastal and inland areas including east of the Cascades. At sites where it was feeding on knotweed, this generalist herbivore was also found on surrounding vegetation, especially grasses.

One of the most damaging insects found was another homopteran, a cicadellid identified as *Graphocephala atropunctata* (a.k.a. *Hordnia circellata*), which is commonly known as the blue-green sharpshooter. *G. atropunctata*

was found only at one site, a roadside patch of *F. x bohemica* near Cascade Head, Oregon, but it was abundant at that site. This species is an important pest of grapes in California, because it is a vector of Pierce's Disease caused by the bacterium *Xyella fastidiosa*. Pierce's Disease is not likely involved at the surveyed site, because it does not occur so far north. In the first visit to the site, eight of ten stems sampled yielded between five and 40 nymphs. Adults were not found at this time. Nymphs feeding on the upper leaves caused the leaves to roll and turn slightly brown. The nymphs were mostly gone and adults were sparse later in the summer, but their feeding had turned many of the leaves brown.

Many aphid species were found on knotweeds but they were neither abundant enough to cause damage nor widespread. Most were found as isolated individuals, probably transients. Only three species were clearly reproducing on the plant. A black aphid, which resembled the bean aphid (*Aphis fabae*), was found at three sites in the northern Puget Sound area. At two of those sites it was found in small colonies of up to 50 aphids among a few leaves (one of these colonies was not part of the quantitative sample and thus not listed in the data table). One individual of the same species was found at a third site. A second, green-brown aphid species was found in the Hells Canyon region of eastern Oregon. This species was consistently tended by ants and was found in groups of 10–15 per stem. A third, small, pale-green aphid was present (1–5 per stem) in a shady site near Big Creek, coastal Oregon and reproducing on *F. sachalinensis*. Whiteflies, probably *Trialeurodes* spp. (Homoptera: Aleyrodidae), were found occasionally in the field, but only in very low abundance. In contrast, in our greenhouse they obtained very high densities on all three knotweed species.

The Chrysomelid beetle, *Galerucella nymphaeae,* was found in abundance at just one site. This native leaf beetle is closely related to the European *Galerucella* species introduced for biological control of purple loosestrife (*Lythrum salicaria*). *G. nymphaeae* was found feeding and laying eggs on *F. sachalinensis* in late August in an upper salt-marsh site on the east side of Willapa Bay, Washington. The plants did not have any larvae on them at the time, nor was there evidence of larval feeding from a previous generation. When the site was revisited in 2005, no *G. nymphaeae* were found.

Within the Lepidoptera, the most abundant species was the woolly bear caterpillar, *Isia isabella* (Lepidoptera: Arctiidae). It was found in both Washington and Oregon, but more often in Washington. *Isia isabella* was usually

found in the egg stage, or as a cluster of gregarious, early-instar caterpillars. Older caterpillars were only rarely found on knotweeds in the field. This species was able to fully complete development on *F. japonica* in the lab. Because it is widely distributed in North America, *I. isabella* could potentially control knotweeds throughout North America. Other lepidopterans included occasional leaf rolling species found primarily at shady sites. In some cases, the larva inside had eaten away at the leaf from inside the roll. In other cases, the leaf seemed to serve only as a shelter and there was no feeding damage. Only one of several individual leaf rollers collected, a Pyralid moth (*Herpetogramma pertextalis*), successfully hatched into an adult.

A variety of slugs and snails was found, ranging from tiny (< 1 cm) to very large (> 8 cm). They were more common early in the summer and in shady, moist sites. Damage was occasionally substantial especially on the lower leaves. Damage diminished later in the season so that the overall impact on the plant was probably negligible.

Stem, root, flower, and seed herbivory

No root feeders or stem borers were found. Occasionally, we found discoloration in roots but never the organism causing it. On two occasions we found holes that had been chewed in the stem. In one of these cases an earwig was inside the stem, but did not appear to be feeding. In the other case, there was frass inside but no organism. No flower or seed feeders were found.

Alaska

Foliar herbivory and damage

Given the sampling effort (128 person-hours), remarkably few invertebrates were collected in the summer of 2004. The foliar collection comprised just 125 specimens, 70 collected in June and 55 collected in September (Appendix 2c), a success rate of less than one specimen per person-hour of searching. We found that about 50 separate taxa were collected off leaf surfaces, representing 40 Families, ten Orders, three Classes, and two Phyla. No individual taxon was abundant, with only three taxa represented by more than ten specimens (Pulmonate Snail—18; Mesostigmatid Mite—11; Spittle Bug—11). Furthermore, the majority of the foliar specimens collected (80 of 125) cannot be considered to be potential natural enemies of knotweed: 38 specimens were either spiders, predaceous mites/insects or parasitoids; nine were springtails; and 33 were flies that were probably using knotweed as a resting habitat. Of the remaining 48,

only spittle bugs (Fig. 5a) and slugs (Fig. 5b) were observed actually feeding on leaves of knotweed. Although we observed some evidence of strip-feeding (Fig. 5c) on knotweed leaves, we were not able to associate this damage definitively with individual insects or mollusks (we did observe a noctuid larva on an undamaged leaf adjacent to a strip-damaged leaf (Fig. 5d). We collected several individual snails and noctuid moths (including late instar larvae); however, none of these individuals were observed actually strip-feeding or leaf-mining knotweed.

Figure 5 Foliar feeding damage on knotweed, southeastern Alaska, June–September, 2004 and 2005. a) Spittlebug froth masses, Sitka Vestovia. b) Slug on heavily-rasped Japanese knotweed leaf, Juneau lab. c) Strip-feeding damage, Juneau lab. d) Strip-feeding damage, Juneau Thane. Photos by Tom Huette.

In 2005, we collected a total of 707 individual specimens, representing nearly a six-fold increase in total abundance over 2004. We collected a total of 119 individual foliar invertebrates in June, and 588 in September (Appendix 2c). About 50 separate taxa, representing at least 67 Families, 11 Orders, three Classes, and two Phyla, were collected off leaf surfaces. The majority (440 of

707) of the foliar specimens collected in 2005 cannot be considered potential natural enemies of knotweed. We collected 81 spiders, 56 parasitoids, 95 springtails, 57 social wasps, and 197 flies that were probably using knotweed as a resting or hunting habitat. Of the remaining 267 herbivorous invertebrates, 167 were snails and 32 were spittle bugs. As in 2004, we did observe spittle bugs and slugs actually feeding on knotweed, but other potential herbivores were simply caught resting on the leaves.

We can identify seven invertebrate taxa, representing 59 individuals, that deserve further attention as biocontrol agents for knotweed (Table 1):

1. two species of *Lygus* bugs (some species of these true bugs are important economic pests in North America).
2. seven individuals within the mite sub-order Actinetida (spider mite taxon) in 2005.
3. three species of leafhoppers (some species in this group have been known to transmit viruses).
4. three species of aphids (many species of aphids have been known to reach damaging numbers, especially on cereals, roses, and greenhouse plants).
5. possibly three species of noctuid moths (these strip feeders often reach numbers that have the potential to defoliate plants).
6. one individual adult anthomyiid (as larvae, these insects bore into stems and roots, and could be responsible for some of the damage we observed in both 2004 and 2005).
7. three species of tenthredenid sawflies (as larvae these insects can defoliate plants much the same way as lepidopteran larvae).

Aside from the formal collection of invertebrates, during the two-year study we observed some potentially significant types of leaf damage. In addition to the strip feeding and skeletonizing observed in 2004, we found many leaves that exhibited damage similar to the type reported caused by chrysomelid beetles in Asia (Fig. 6, page 18). As is true of many leaf beetles, the damage we observed appeared to be caused by pit feeding, which spread throughout the surface area of the leaf, eventually skeletonizing it. At the two Juneau sites, we observed leaf damage similar to that known to be caused by the fungus *Puccinia* sp. in the native habitat of Japanese knotweed. Other types of unidentified leaf damage include leaf curl and a possible leaf fungus, both of which

Table 1 Herbivorous insect species observed feeding on knotweed.

Classification	Notes	State Totals	
		OR/WA	AK
INSECTA			
Hemiptera			
Aphidae			
Aleyrodidae			
Trialeurodes sp. (white)	Polyphagous sap feeder	17	
Aphis fabae	Polyphagous sap feeder	51	
Small pale yellow aphid		15	
Brown green ant-tended aphid		31	
Pale green aphid		3	
Cercopidae			
Philaenus spumarius	Native polyphagous herbivore	58	32
Cicadellidae			
Balclutha manitou (Gillette & Baker)	Native polyphagous herbivore		2
Graphocephala atropunctata	polyphagous sap feeder	151	
Empoasca sp.	polyphagous sap feeder	27	
Evacanthus grandipes Hamilton	Native polyphagous herbivore		2
Idiocerus couleanus Ball & Parker	Native willow-feeding herbivore		2
Coccidae			
Brown scale	Polyphagous sap feeder	2	
Miridae			
Orthops scutellatus Uhler	Native; feed on Apiaceae		5
Pentatomidae			
Euchistus spp.	Polyphagous sap feeder	7	
Coleoptera			
Chrysomelidae			
Gallerucella nymphaeae	Native polyphagous herbivore	29	
Curculionidae			
Sitona lineatus	Introduced; pest of legumes	4	
Otiorhynchus sulcatus (Fabricius)	Native; larvae polyphagous root feeder; adult leaf feeder		1
Elateridae			
Ctenicera lobata (Eschscholtz)	Native; feeding habits unknown		1
Diptera			
Dryomyzidae			
Dryomyza sp.	Native; larvae feed on decaying plants		1
Hymenoptera			
Tenthredenidae			
Ametastegia glabrata	Widespread in northern hemisphere; polyphagous	1	
Eriocampa ovata Linnaeus	Native; larvae feed on *Alnus* sp.		2
Tenthredo varipicta Norton	Native; larva feeding habits unknown		2
Lepidoptera			
Arctiidae			
Isia isabella	Native; larvae polyphagous leaf feeders	27	
Pyralidae			
Herpetogramma pertextalis	Larvae roll and feed on leaves	3	
Total Abundance		**426**	**50**
Total Number of Taxa		**14**	**10**

Figure 6 Possible pit-feeding leaf damage on knotweed in southeastern Alaska, September 2005. Inset: Chrysomelid beetle larva, *Gallerucida bifasciata,* feeding on Japanese Knotweed, Japan, 1999. Photo by Tom Huette; inset by Richard Shaw.

might merit further study. Finally, in both years we observed sun scald, especially at the Sitka Verstovia site, that apparently begins when leaves are young, persists through leaf development, and can eventually cause leaf splitting. Observations of young leaves indicated that sun scald began on leaf ridges parallel to the mid-rib, and then expanded and intensified as the leaf matured. In June, 2004, at one site along the road east of Sitka, we observed sun scald on nearly every leaf in the population.

Stem, root, flower and seed herbivory

In 2004, just eleven individual invertebrates were collected from within stems and roots (Table 2). Nine of those were collected from within stems; they may have been using the interior of the stems as resting habitat. In each case, the type of damage we observed suggested these individuals had accessed the interior of the stem through an existing hole (Fig. 7, page 20). The list of taxa collected from within stems supports this hypothesis, as most of the species are

not known to be interior stem feeders (e.g. snails, thrips, soldier beetles; Table 2). The other two invertebrates were collected from within roots, and each observation was associated with existing root damage. Again, slugs and ground beetles are not known to be root feeders. Although we did not observe or collect any stem or root boring invertebrates in the act of feeding, we did observe damage associated with stem and root feeding. Stem damage was comparatively less common: we observed six cases (out of about 250 stems examined), in which stems were clearly damaged on the interior and contained frass and necrotic tissue that likely resulted from invertebrate feeding. In all cases, the damage was confined to a single chamber delimited by stem septa. The feeding invertebrate that caused this damage had gained access to the chamber but did

Table 2 List of invertebrate taxa (identified to family and sub-order level) collected from stems and roots in Juneau and Sitka, Alaska, June and September, 2004. Note: No samples were collected at Kimsham 2 and Verstovia in June, 2004.

Date	Within Stems	#	Within Roots	#	Total
June 2004					
Juneau Lab	Snail – tiny	2		0	2
	Mesostigmatid mite	1		0	1
Juneau Thane	Snail – large	1		0	1
	Cantharid beetle	1		0	1
Sitka Kimsham	Thrips	1	Slug	1	2
Total (June)		**6**		**1**	**7**
September 2004					
Juneau Lab	0	0		0	0
Juneau Thane	0	0		0	0
Sitka Kimsham 1	Slug	2		0	2
	Noctuid moth larva	1		0	1
Sitka Kimsham 2	0	0	Carabid beetle	1	1
Sitka Verstovia	0	0		0	0
Total (September)		**3**		**1**	**4**
June 2005					
Juneau Lab	0	0	0	0	0
Juneau Thane	0	0	0	0	0
Sitka Kimsham	0	0	0	0	0
Sitka Verstovia	0	0	0	0	0
Total (June)	**0**	**0**	**0**	**0**	**0**
September 2005					
Juneau Lab	Slug	1	Noctuid	1	2
Juneau Thane	0	0	0	0	0
Ketchikan Ward Bay	0	0	0	0	0
Sitka Kimsham	0	0	0	0	0
Sitka Verstovia	0	0	0	0	0
Total (September)	**0**	**1**	**0**	**1**	**2**

Figure 7 Stem damage on knotweed, southeastern Alaska, possibly caused by herbivory, June–September, 2004 and 2005. Photos by Tom Huette.

not penetrate adjacent septa. In 2005, we found only a slug within one stem, and a noctuid larva on the outside of an excavated root, possibly preparing to over-winter in the adjacent soil.

More common were observations of apparent feeding damage within roots. In some cases, damage was limited to only a small volume of the interior of the root; in other cases, long sections of root interiors were damaged (Figs. 8a, b). In 2004, we observed about 120 cases of root damage in about 4,500 roots (~2.7% incidence). In 2005, the incidence of this kind of damage was 5.1 % overall, between 3 and 5% at the Juneau, Ketchikan, and Sitka Kimsham sites. We observed a much higher incidence of root damage in September at the Verstovia site, when we excavated a young plant that had a much lower root volume. Out of just 120 root sections, we found 33 sections that were damaged, an incidence of 28%. The water table was very high at this excavation site, which, together with the age of the plant, probably contributed to the low root volume. At most sites, most of the root damage was observed in the upper half of the depth profile of the excavation. In no case could we assign a specific cause to the damage; no root-boring herbivores were observed feeding in roots, and we extracted no potential root borers from Berlese funnels of root tissue in September, 2005. Also, even with the relatively higher incidence of damage at the Verstovia Site, we were not able to associate root damage with effects on the above-ground portion of the plants. Also in September, 2005, we made an unusual observation on roots at the Sitka Kimsham site. One of the major roots yielded a mass of milky-white, sac-like tissue, packed into the interior of the root, right at the junction of stem and root (Fig. 8c).

Finally, no flower or seed feeders were found.

Discussion

The most striking observation from this two-year survey of knotweed invertebrates in the Pacific Northwest was the relatively low numbers of herbivorous invertebrates collected. Moreover, most of the invertebrates observed tended to use the plant as resting habitat. For example, a large number of pulmonate snails were collected on leaf surfaces, but feeding damage was rarely associated with them. Many individual Diptera were collected as well, but only a few individuals belonged to groups known to be herbivorous in the larval stage.

Another surprising observation was the generally low abundance of either web-spinning or hunting spiders using knotweed as a hunting habitat. One expects spi-

Figure 8 Root damage on Japanese knotweed in southeastern Alaska, possibly caused by herbivory, June 2004, September 2005. a) Root-borer damage, Juneau Thane. b) Extensive root-borer damage, Juneau Thane. c) Unidentified masses within root, Sitka Kimsham. Photos by Tom Huette.

ders to be common on foliar surfaces whenever their prey are common. Hence, the number of insects on knotweed might have been insufficient to attract and hold large numbers of hunting spiders.

Observations of damage to leaves, stems and roots were relatively rare, especially compared to our observations of other plants. Nonetheless, several kinds of leaf damage were observed during the two-year survey, including: 1) pit-feeding similar to that caused by chrysomelid beetles; 2) apparent fungal infection, similar to that known to be caused by the fungus *Puccinia* sp. in Japan; and 3) an unidentified leaf curl. We observed damage associated with stem and root feeding, but did not observe stem or root boring invertebrates actually in the act of feeding. In southeastern Alaska, we observed nine cases (out of about 550 stems examined), in which stems were clearly damaged on the interior and contained frass and necrotic tissue likely resulting from invertebrate feeding. Roots were more likely to be damaged than stems; in southeastern Alaska, we observed that about 4% (245 out of about 5,950) of root sections had some kind of interior damage.

The relatively low numbers of herbivores, and low levels of herbivory observed in this survey, are mirrored by other knotweed surveys in North America. An extensive search for knotweed natural enemies has been conducted in the northeastern U.S. by Bernd Blossey (with John Maerz and Victoria Nuzzo). In a survey of about 50 knotweed patches, Blossey et al. (2002) noted that the herbivore community of knotweed was extremely small, with most of the visible feeding damage associated with the introduced Japanese beetle (*Popillia japonica)* adults, and larvae of a stem-mining weevil (unidentified). Neither of these were found on knotweed in the Pacific Northwest. One sawfly adult was found ovipositing on northeastern plants by Blossey. His description (pers. comm.) matches the species we found on the native *Polygonum* in the Pacific Northwest, probably *Ametastegia glabrata*, the dock sawfly, which is reported throughout the U.S. Overall, their conclusion was that "there are no potential natural enemies in North America that may be used as biological control agents for Japanese knotweed." Similarly, the results of a survey by Beerling and Dawah (1993) prompted these authors to exclaim, "...if maximizing phytophagous insect diversity is considered important on nature reserves then clearly *F. japonica* represents a threat to the aims of the conservationist."

In contrast to the situation in the U.S. (and the United Kingdom), in its native Japan damage to *F. japonica* by invertebrates and pathogens can be high (Shaw, 1995), and invertebrate diversity is much higher, with 186 species of phytophagous insects recorded (Shaw and Seiger 2002). Stem-mining Lepidoptera found in the internodal sections of stems are so numerous in Japan they are regularly used as fishing bait

(Sukopp and Starfinger, 1995). Other stem boring and root boring insects (*Ostrinia ovalipennis* and *O. latipennis*; Crambidae) are known to feed on knotweed species in Japan (Ohno et al. 2003). The genus *Ostrinia* includes agricultural pests such as the Asian and European corn borers, which can cause extensive plant damage. Interestingly, damage to leaves caused by the chrysomelid beetle, *Gallerucida bifasciata,* in Japan (Zwolfer 1973) is similar in appearance to damage we observed in southeastern Alaska, an observation that may warrant further study. Other leaf damage observed in Japan, and similarly observed in our survey, is that caused by the fungal pathogen, *Puccinia polygoni-weyrichii* Miyabe. Overall, the combination of insect and fungal agents can severely damage the plant in its native range, and could be useful as potential control agents in the U.S. Our results confirm that none of the Asian insects or pathogens that are candidate species for the biological control program (as reported in the CABI 2003 report) were found in Oregon, Washington, or Alaska. Therefore, research to test and import these specialist natural enemies is valuable.

Current Status of Biological Control Program

An international team of scientists from the United States, Canada, and the United Kingdom is currently testing two knotweed-feeding insects imported from Japan as potential biological control agents for knotweeds: a sap-feeding psyllid (*Aphalara itadori)*, and a leaf- and stem-feeding moth (*Ostrinia ovalipennis).* Three additional species, a moth (*O. latipennis*), a leaf beetle (*Gallerucida bifasciata)*, and a weevil (*Lixus impressiventris*), also were considered, but eliminated after they were found to feed on plants other than the target weed. Recently, *A. itadori*, was approved for release in the United Kingdom (Shaw, pers. comm.). Testing of this species for a release in North America is near completion. Testing of *O. Ovalipennis* has just begun and could take up to 2 years to complete.

Biocontrol agents are only approved for release into the environment after a thorough demonstration that they will not harm native or economically important plant species. The candidate biocontrol insects are being tested for their ability to feed and develop on over 70 plant species in North America, with an emphasis on plants that are closely related to knotweed. Test results will be submitted for review to the Technical Advisory Group on Biological Control of Weeds for a possible release in 2011.

Possible release sites

Several potential release areas in Oregon and Washington were identified in the event that safe and effective biocontrol agents are approved for introduction. In most cases, specific arrangements have not been made with any particular land owner or agency. Our list includes sites that have expansive areas of knotweed that would be difficult to control by other means. In contrast, the five sites examined in southeastern Alaska are much smaller in extent, and could be controlled effectively with the use of herbicides; however, there may be public resistance to the use of herbicides in Sitka and Juneau.

Naselle, Pacific County, Washington

Naselle is a small town in the Willapa Hills of Pacific County in southeastern Washington. The Naselle River and several of its tributaries are choked with what appears to be the hybrid *F. x bohemica*. The area is not considered high priority for eradication by herbicides because of the large volume of knotweed present. Habitats include streamside, upland, sunny, and shady sites. Infested properties are primarily private residences and logging company lands but there is at least one stretch of publicly owned river maintained by the Washington Department of Fish and Wildlife.

Cedar River, King County, Washington

The knotweed infestation is heaviest in the lower end of the river but can be found many miles upstream and in some of the tributaries. The Cedar River is important salmon spawning habitat. The King County Parks Department has expressed interest in being included in the initial biocontrol releases. The deparment manages several tracts of public, undeveloped, riverside property that is choked with knotweed (probably the hybrid). One site, Cavanaugh Pond, was found to be especially suitable because of an active, volunteer-supported restoration project underway. The project is seriously threatened by knotweed re-invasion. At the time of our visit, the county had no intentions of using herbicides in its restoration work. A fraction of the 28-acre tract has been cleared (mowed) of knotweed and replanted with native species, but knotweed was re-sprouting around the native plantings.

Stillaguamish, Snoqualmie, and Skagit Rivers, Washington

There are many possibilities for release along these rivers, warranting further investigation. Due to active, ongoing control work for knotweed, it would be

best to wait until biocontrols are available before setting aside any release sites in these areas.

Forks, Clallam Co., Washington

Knotweed is present along the Hoh, Calawah, and other area rivers. The county has an active spray program in progress, but many locations are very difficult to access and biocontrol will likely be needed. The University of Washington Olympic Natural Resources Center is located in Forks and could provide assistance and/or coordinate releases with the county.

Lower Nahelem River, Tillamook Co., Oregon

The Nehalem River is probably the most knotweed-infested river in Oregon. Hybrid knotweed, *Fallopia x bohemica,* infests a 30-mile stretch between Jewell and Nehalem, primarily inside the Tillamook State Forest. The river is accessible along its length by a dirt road that parallels the river. A couple of very large stands, several acres in size, are present on private property near Mohler, Oregon. These would make ideal initial-release sites.

Big Creek, Lane Co., Oregon

This creek flows from the Coast Range to the sea. A very large infestation of giant knotweed, *Fallopia sachalinenis* (Fig. 2, page 8) is present near the mouth of the creek that is visible from highway 101. The knotweed is abundant along the banks of the creek for at least 3 miles upstream. A dirt road parallels the creek for easy access. The area is largely owned by the U.S. Forest Service.

Luckiamute River, Benton and Polk Cos., Oregon

This river runs from the Coast Range into the Willamette Valley and there is knotweed growing along much of the banks. Being in the vicinity of Corvallis and Oregon State University, it would perhaps make a convenient study area for an Oregon State University graduate student.

Hells Canyon Region, Baker Co., Oregon

The Hells Canyon region, including the Snake and Inmaha Rivers, has several knotweed infestations that are difficult to access and thus would be difficult to control other than with biological control.

Mill Creek, Asotin Co., Washington

This creek is heavily infested where it crosses the Oregon and Washington border. It includes a mix of private and public land. Knotweed is abundant along the creek and roadside. Substantial patches can be found in private yards.

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APPENDIX 1. KNOTWEED SITES, PACIFIC NORTHWEST, 2004 AND 2005.

Site Name	Site Code	State	Elev. (m)	Lat. (dd)	Long.	Knotweed Species	Exposure	Environment
Juneau Lab	JL	AK	30	58.22	-134.36	*F. japonica*	Shade	Wet
Juneau Thane	JT	AK	5	58.16	-134.21	*F. japonica*	Shade	Oceanside
Sitka Kimsham	SD	AK	25	57.03	-135.20	*F. x bohemica*	Sun	Upland
Sitka Verstovia	SV	AK	25	57.03	-135.18	*F. x bohemica*	Shade	Upland
Ketchikan	KC	AK	30	55.32	-131.40	*F. x bohemica*	Shade	Upland
West Port	12	WA	0	46.86	-124.09	*F. japonica* or *F. x bohemica*	Sun	Upland
Hoquium	13	WA	0	47.04	-123.92	*F. japonica* or *F. x bohemica*	PS	Upland
North of Amanda Park	14	WA	176	47.48	-124.06	*F. japonica* or *F. x bohemica*	Sun	Upland
South of Forks	15	WA	109	47.90	-124.36	*F. japonica* or *F. x bohemica*	Sun	Upland
Calawah River	16	WA	61	47.96	-124.39	*F. sachalinensis*	PS	Streamside
Pleasant Valley	17	WA	138	48.08	-124.27	*F. japonica* or *F. x bohemica*	Sun	Upland
Sapho Junction	18	WA	147	48.07	-124.28	*F. sachalinensis*	Sun	Upland
East Port Angeles	19	WA	93	48.10	-123.33	*F. japonica* or *F. x bohemica*	Sun	Upland
McAleer Creek	20	WA	86	47.76	-122.30	*F. japonica* or *F. x bohemica*	Shade	Streamside
Snohomish	21	WA	25	47.93	-122.10	*F. sachalinensis*	Sun	Upland
Lake Stevens	22	WA	99	48.01	-122.11	*F. japonica* or *F. x bohemica*	Sun	Upland
Stillaguamish River	23	WA	23	48.20	-122.13	*F. japonica* or *F. x bohemica*	Sun	Streamside
Samish River	24	WA	24	48.55	-122.34	*F. x bohemica*	Shade	Streamside
Skagit River	25	WA	0	48.42	-122.34	*F. x bohemica*	Shade	Streamside
Cowlitz River 1	26	WA	15	46.27	-122.90	*F. japonica* or *F. x bohemica*	PS	Upper bank
Cowlitz River 2	27	WA	10	46.26	-122.90	*F. japonica* or *F. x bohemica*	Sun	Upper bank
Cathlamet	28	WA	5	46.23	-123.39	*P. wallichii*	Sun	Wet
Naselle River	29	WA	20	46.37	-123.78	*F. x bohemica*	Sun	Streamside
Columbia River	30	WA	1	46.26	-123.85	*F. x bohemica*	Sun	leymus
Bean Creek 1	31	WA	26	46.31	-123.80	*F. x bohemica*	Shade	Streamside
Bean Creek 2	32	WA	26	46.31	-123.80	*F. x bohemica*	Sun	Upland
Long Beach	33	WA	0	46.36	-124.03	*F. japonica* or *F. x bohemica*	Sun	Upland
North Bend	58	WA	110	43.09	-76.12	*F. japonica* or *F. x bohemica*	Sun	Streamside
Pullman 1	59	WA	110	46.72	-117.17	*F. japonica* or *F. x bohemica*	PS	Upland
Pullman 2	60	WA	1491	46.73	-117.17	*F. japonica* or *F. x bohemica*	Sun	Upland
Steptoe	61	WA	2093	46.98	-117.30	*F. japonica* or *F. x bohemica*	Sun	Upland
Mill Creek 1	62	WA	495	46.01	-118.12	*F. japonica* or *F. x bohemica*	PS	Upper bank
Mill Creek 2	63	WA	541	46.03	-118.14	*F. japonica* or *F. x bohemica*	Sun	Streamside
Cow Creek 1	64	WA	387	45.77	-116.74	*F. japonica* or *F. x bohemica*	Sun	Streamside
Sid Snyder Road	69	WA	20	46.35	-124.04	*P. wallichii*	Sun	Upland
Ilwaco 2	70	WA	95	46.30	-124.05	*F. japonica* or *F. x bohemica*	Sun	Upland
Naselle Boat Launch	71	WA	27	46.37	-123.78	*F. x bohemica*	PS	Streamside
Bean Creek	72	WA	26	46.31	-123.80	*F. x bohemica*	Sun	Upland
Youngs River	1	OR	0	46.09	-123.75	*F. sachalinensis*	Shade	Upper bank

Appendix 1. Knotweed sites, Pacific Northwest, 2004 and 2005, *cont.*

Site Name	Site Code	State	Elev. (m)	Lat. (dd)	Long.	Knotweed Species	Exposure	Environment
Olney	2	OR	5	46.06	-123.69	*F. japonica* or *F. x bohemica*	Shade	Streamside
Hillsborough	4	OR	39	45.46	-122.99	*F. japonica* or *F. x bohemica*	PS	Upland
Astoria 1	5	OR	77	46.18	-123.84	*P. wallichii*	Sun	Upland
Astoria 2	6	OR	72	46.18	-123.84	*P. wallichii*	PS	Upland
Seaside 1	34	OR	4	46.00	-123.91	*F. japonica* or *F. x bohemica*	PS	Upland
Seaside 2	35	OR	14	45.96	-123.92	*P. wallichii*	PS	Upper bank
Seaside 3	36	OR	4	45.94	-123.92	*F. japonica* or *F. x bohemica*	Sun	Upland
Manzanita 1	37	OR	17	45.72	-123.90	*P. wallichii*	Sun	Upland
Manzanita 2	38	OR	17	45.72	-123.90	*F. japonica* or *F. x bohemica*	Sun	Upland
Wheeler	39	OR	11	45.69	-123.88	*P. wallichii*	Sun	Upland
Manhattan Beach	40	OR	16	45.64	-123.94	*F. japonica* or *F. x bohemica*	Sun	Upland
Trask River 2	41	OR	0	45.48	-123.85	*F. japonica* or *F. x bohemica*	Sun	Streamside
Trask River 1	42	OR	51	45.46	-123.68	*F. japonica* or *F. x bohemica*	Sun	Streamside
Trask River 3	43	OR	63	45.46	-123.68	*F. japonica* or *F. x bohemica*	Sun	Upper bank
Neskowin River 1	44	OR	38	45.08	-123.93	*P. wallichii*	Sun	Upper bank
Neskowin River 2	45	OR	31	45.08	-123.95	*F. sachalinensis*	PS	Upland
Cascade Head	46	OR	16	45.03	-123.96	*F. x bohemica*	Sun	Upland
Big Creek 1	47	OR	0	44.17	-124.11	*F. sachalinensis*	Sun	Streamside
Big Creek 2	48	OR	3	44.17	-124.10	*F. sachalinensis*	Shade	Upland
Big Creek 3	49	OR	3	44.17	-124.10	*F. sachalinensis*	PS	Wet
Tahkenitch Landing	50	OR	11	43.80	-124.15	*P. wallichii*	Sun	Upland
Reedsport	51	OR	0	43.35	-124.20	*F. japonica* or *F. x bohemica*	Sun	Upland
Coos Bay	52	OR	55	43.40	-124.60	*F. japonica* or *F. x bohemica*	Sun	Upland
Remote	53	OR	71	43.00	-123.88	*F. japonica* or *F. x bohemica*	Sun	Upland
Cottage Grove	54	OR	205	43.82	-123.05	*F. japonica* or *F. x bohemica*	Sun	Upland
Unknown	55	OR	140	44.02	-123.02	*F. japonica* or *F. x bohemica*	PS	Upland
Scappoose	56	OR	35	45.77	-122.88	*F. japonica* or *F. x bohemica*	PS	Streamside
Cow Creek 2	65	OR	364	45.77	-116.75	*F. japonica* or *F. x bohemica*	Sun	Streamside
Inmaha trail 1	66	OR	363	45.78	-116.74	*F. japonica* or *F. x bohemica*	Shade	Upper bank
Inmaha trail 2	69	OR	304	45.77	-116.75	*F. japonica* or *F. x bohemica*	Sun	Upper bank
Blue Mtns.	70	OR	303	45.79	-118.25	*F. sachalinensis*	PS	Upland
Lake Forest Park	3	WA	58	47.77	-122.31	*F. x bohemica*	PS	Upper bank
Astoria Shively	7	WA	69	46.18	-123.83	*F. sachalinensis*	PS	Upland
Ilwaco	8	WA	11	46.30	-124.04	*F. japonica* or *F. x bohemica*	Sun	Upland
South Bend	9	WA	0	46.67	-123.82	*P. wallichii*	PS	Upper bank
Raymond 1	10	WA	0	46.68	-123.74	*F. x bohemica*	Sun	Upland
Raymond 2	11	WA	3	46.69	-123.74	*F. x bohemica*	Sun	Upland

Appendix 2A. Invertebrates collected from foliar surfaces of Japanese Knotweed, Oregon, April–September 2004

Classification	Site #																										
	1	2	5	6	34	35	36	37	39	40	41	44	45	46	47	48	49	50	51	52	54	56	65	66	69	70	Total
MOLLUSCA																											
GASTROPODA																											
Stylommatophora																											
Slug	4		1																								5
ARTHROPODA																											
ARACHNIDA																											
Acari																											
Mite 2																										100	100
INSECTA																											
Orthoptera																											
Tettigoniidae																											
Tettigoniidae 1																							1				1
Hemiptera																											
Aleyrodidae																											
Trialeurodes sp.							1		2	2						1											6
Aleyrodidae 1	2																										2
Aphididae																											
Aphididae 1																15											15
Aphididae 2																								31			31
Aphididae 4									1										1								2
Cercopidae																											
Philanus spumarius	1		2	1		5	1	1	2	2																	15
Cicadellidae																											
Graphocephala atropunctata														150								1					151
Empoasca sp.																24	3										27
Cicadellidae 1	3																										3
Cicadellidae 2							1																				1
Cicadellidae 3															1												1
Cicadellidae 4																2											2
Cicadellidae 6	1																	1			2						4
Miridae																											
Miridae 2					1																						1
Miridae 3																4											4
Tingidae																											
Tingidae 2									3																		3

Appendix 2A. Invertebrates collected from foliar surfaces of Japanese Knotweed, Oregon, April–September 2004, *cont.*

Classification	Site #																										
	1	2	5	6	34	35	36	37	39	40	41	44	45	46	47	48	49	50	51	52	54	56	65	66	69	70	Total
Coleoptera																											
Curculionidae																											
Curculionidae 1					1																						1
Curculionidae 3																										3	3
Curculionidae 4		1			1						1																3
Lepidoptera																											
Geometridae																											
Geometridae 1																				1							1
Unidentified familiy												2									1						3
Diptera																											
Unidentified family																1											1
Hymenoptera																											
Tenthridinidae																											
Unidentified adults													2												2		4
Unknown - Pearly white eggs																						1					1
TOTAL*	11	1	3	1	3	5	3	1	8	4	1	2	2	150	1	47	3	1	1	1	3	2	1	31	2	103	391

*Total = page 33, 34.

Appendix 2B. Invertebrates collected from foliar surfaces of Japanese Knotweed, Washington State, April–September 2004.

Classification	Site #																														
	3	7	8	9	12	13	14	16	17	19	20	21	22	23	24	25	26	28	31	32	59	60	61	62	63	64	71	72	73	74	75	Total
MOLLUSCA																																
GASTROPODA																																
Stylommatophora																																
Slug		3																														3
Snail					1																											1
ARTHROPODA																																
ARACHNIDA																																
Acari																																
Mite 1								20																								20
Mite 2																											50					50
INSECTA																																
Orthoptera																																
Acrididae																																
Acrididae 1																														1		1
Hemiptera																																
Aleyrodidae																																
Trialeurodes sp.						1					10																					11
Aleyrodidae 3											5																					5
Aleyrodidae 4		1						2																								3
Aphididae																																
Aphis fabae												50	1																			51
Aphididae 3		1	1								1																					3
Aphididae 4				1				1			1						1															4
Cercopidae																																
Philanus spumarius		7	1		2	2	3			8		1	4	2	1	1		1			2	2	4	1			1					43
Cercopidae 1						1			1																							2
Cicadellidae																																
Cicadellidae 1		1																													1	2
Cicadellidae 2														1																		1
Cicadellidae 5																					1	5										6
Cicadellidae 6				1																						3		1				5
Coccidae																																
Coccidae 1			1																1													2

Appendix 2B. Invertebrates collected from foliar surfaces of Japanese Knotweed, Washington State, April–Sept. 2004, *cont.*

Classification	Site #																														
	3	7	8	9	12	13	14	16	17	19	20	21	22	23	24	25	26	28	31	32	59	60	61	62	63	64	71	72	73	74	75	Total
Miridae																																
Miridae 1											3																					3
Miridae 4		1					1																									2
Pentatomidae																																
Euchistus spp.																					2		5									7
Pentatomidae 1																										1				1		2
Tingidae																																
Tingidae 1		1																														1
Psocoptera																																
Psocidae 1																												40	21	1	8	70
Coleoptera																																
Curculionidae																																
Sitona lineatus																					1	3										4
Curculionidae 2																					25		1									26
Curculionidae 4		1																														1
Lepidoptera																																
Arctiidae																																
Isia isabella (larvae)					25		2																									27
Isia isabella (eggs)	1						1							1						1												4
Pyralidae																																
Herpetogramma pertextalis											3																					3
Unidentified familiy	1																										1					2
Diptera																																
Unidentified family																															2	2
Hymenoptera																																
Tenthridinidae																																
Ametastegia glabrata																														1		1
Unidentified adults																						1			1							2
Dermaptera																																
Unidentified adults		1																			2											3
Unknown - Pearly white eggs																													1			1
TOTAL*	2	17	3	2	28	4	7	23	1	8	23	51	5	4	1	1	1	1	1	1	33	11	10	1	1	4	52	41	22	4	11	374

*Total = page 35, 36.

Appendix 2C. Invertebrates collected from foliar surfaces of Japanese Knotweed in Alaska, June–September 2004, 2005.

Classification	Juneau Lab				Juneau Thane				Sitka Dump					Sitka Verstovia			Ketch	
	Jn04	Sp04	Jn05	Sp05	Jn04	Sp04	Jn05	Sp05	Jn04	Sp04	Sp04	Jn05	Sp05	Sp04	Jn05	Sp05	Sp05	Total
MOLLUSCA																		
GASTROPODA																		
Stylommatophora																		
Slug	1												1					**2**
Snail	6	12	17	78				22								1	30	**166**
ARTHROPODA																		
ARACHNIDA																		
Acari																		**0**
Actinetida				1			4	1							1			**7**
Mesostigmata									11									**11**
Opiliones																		**0**
Phalangiidae										1								**1**
Araneae																		
Agelenidae								1										**1**
Anyphaenidae											1		2			1	1	**5**
Araneidae										2			3	1		9	3	**18**
Clubionidae				1											1			**2**
Dictynidae										1								**1**
Gnaphosidae														1				**1**
Linyphiidae				13									2	1		22	7	**45**
Micryphantidae																	1	**1**
Tetragnathidae				3				1			1				2			**7**
Theridiidae		1		1														**2**
Unidentifiable Egg Mass	1										1							**2**
INSECTA																		
Collembola																		
Isotomidae				6				5					3	7		15		**36**
Sminthuridae				24				16					2	2		7	8	**59**
Plecoptera								2										**2**
Hemiptera																		
Aphididae								1					1		9	2	3	**16**
Cercopidae	3		5				4	1	7	1		3			7	1		**32**

Appendix 2C. Invertebrates collected from foliar surfaces of Japanese Knotweed in Alaska, June–September 2004, 2005, *cont.*

Classification	Juneau Lab				Juneau Thane				Sitka Dump					Sitka Verstovia			Ketch	
	Jn04	Sp04	Jn05	Sp05	Jn04	Sp04	Jn05	Sp05	Jn04	Sp04	Sp04	Jn05	Sp05	Sp04	Jn05	Sp05	Sp05	Total
Cicadidae															2			2
Cicadellidae																		0
Balclutha manitou	1																	1
Evacanthus grandipes								1										1
Idiocerus couleanus															4			4
Miridae																		0
Orthops scutellatus	1		2				1						1					5
Lygus sp.					1									1	3			5
Pentatomidae				1														1
Psyllidae				1			1	1									2	5
Coleoptera																		
Cantharidae							3					2						5
Cerambycidae																1		1
Chrysomelidae									2									2
Coccinellidae																		0
Adalia bipunctata																	1	1
Curculionidae																		0
Otiorhynchus sulcatus			1															1
Elateridae																		0
Ctenicera lobata												1						1
Meloidae					1				1									2
Staphylinidae								1	1						2			4
Lepidoptera																		
Noctuidae (larva)	1		3	1			5	1	3		1			2	1	2		20
Geometridae (larva)															1			1
Diptera																		
Anthomyiidae																1		1
Bibionidae			2		2		7							1				12
Calliphoridae															1			1
Cecidomyiidae	5																	5
Chironomidae		1					1	4		5			1	1		2	3	18

Appendix 2C. Invertebrates collected from foliar surfaces of Japanese Knotweed in Alaska, June–September 2004, 2005, *cont.*

Classification	Juneau Lab				Juneau Thane				Sitka Dump					Sitka Verstovia			Ketch	
	Jn04	Sp04	Jn05	Sp05	Jn04	Sp04	Jn05	Sp05	Jn04	Sp04	Sp04	Jn05	Sp05	Sp04	Jn05	Sp05	Sp05	Total
Chloropidae			1				1											2
Culicidae	1																	1
Dolichopodidae	2																	2
Drosophilidae					1												1	2
Empididae					1													1
Leptogastridae				1														1
Muscidae								3	4							2	1	10
Mycetophilidae				7			1									1	5	14
Ottitidae				2														2
Phoridae																1	2	3
Psocidae								5										5
Psychodidae	1	1								1								3
Sciaridae																6	5	11
Syrphidae				1					1			1	1				2	6
Tachinidae							1	2	1									4
Tepritidae				2												1	2	5
Tipulidae		1														1		2
Brachycera			3		1											1		5
Acalyptrate Muscoid	3		5	48	2		2	4					7			6	38	115
Hymenoptera																		
Bombus sp.								1					1					2
Tenthredenidae																		0
Eriocampa ovata								2										2
Tenthredo varipicta															1		1	2
Braconidae	4			5			1	1					2			8	2	23
Ichneumonidae																3		3
Chalcidoidea			2	5			4	1						6		2	4	24
Cynipidae				1				1					1			1		4
Myrmaridae		1					1											2
Proctotrupidae																2	2	4
Vespidae				10				35					5			7		57
TOTAL*	**30**	**17**	**41**	**212**	**9**	**0**	**37**	**113**	**31**	**11**	**4**	**7**	**33**	**23**	**35**	**106**	**124**	**833**

*Total = page 37–39.